A Proposed Biogeographic Assessment of the Northwestern Hawaiian Islands to Support the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve:

Draft Project Plan

Prepared
December 28, 2005

By
NOAA's National Ocean Service
NCCOS Biogeography Team
and the
NWHI Coral Reef Ecosystem Reserve

A Biogeographic Assessment of the Northwestern Hawaiian Islands to Support the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve:

BACKGROUND

With coral reefs in many places around the world in decline (GCRMN 2004), it is extremely rare to be able to study a coral reef ecosystem that is relatively free of human influence and is comprised of many different coral reef habitats (e.g., corals & algae). The remoteness and limited fishing activities that have occurred in the Northwestern Hawaiian Islands (NWHI) have resulted in minimal human impacts. Therefore, the NWHI provide a unique opportunity to assess how a relatively undisturbed coral reef ecosystem functions in the absence of major human intervention (Friedlander and DeMartini 2002).

The NWHI consist of small islands, atolls, submerged banks, and reefs, and stretch for more than 2,000 km northwest of the high windward main Hawaiian Islands (MHI; Figure 1). From Nihoa and Necker Island (~7 and 10 million years old respectively) to Midway and Kure Atolls (~28 million years old), the NWHI represent the older portion of the emergent archipelago (Juvik and Juvik, 1998). The majority of the islets and shoals remain uninhabited, although Midway, Kure, Laysan Island, and French Frigate Shoals have all been occupied for extended periods over the last century by various government agencies. The remoteness and limited reef fishing activities in the NWHI have resulted in minimal anthropogenic impacts. As a result, the continuing presence of large apex predators such as jacks and reef sharks is one of the most striking and unique components of the NWHI ecosystem. These top carnivores are no longer present in any abundance in the inhabited Hawaiian Islands. The NWHI flora and fauna include a large percentage of species that are endemic to the Hawaiian Islands, which are recognized for having some of the highest marine endemism in the world. The faunas of isolated oceanic archipelagos like the Hawaiian Islands represent species conservation hotspots that have become increasingly important in the context of worldwide declines in the biodiversity of coral reef ecosystems (DeMartini and Friedlander, 2004).

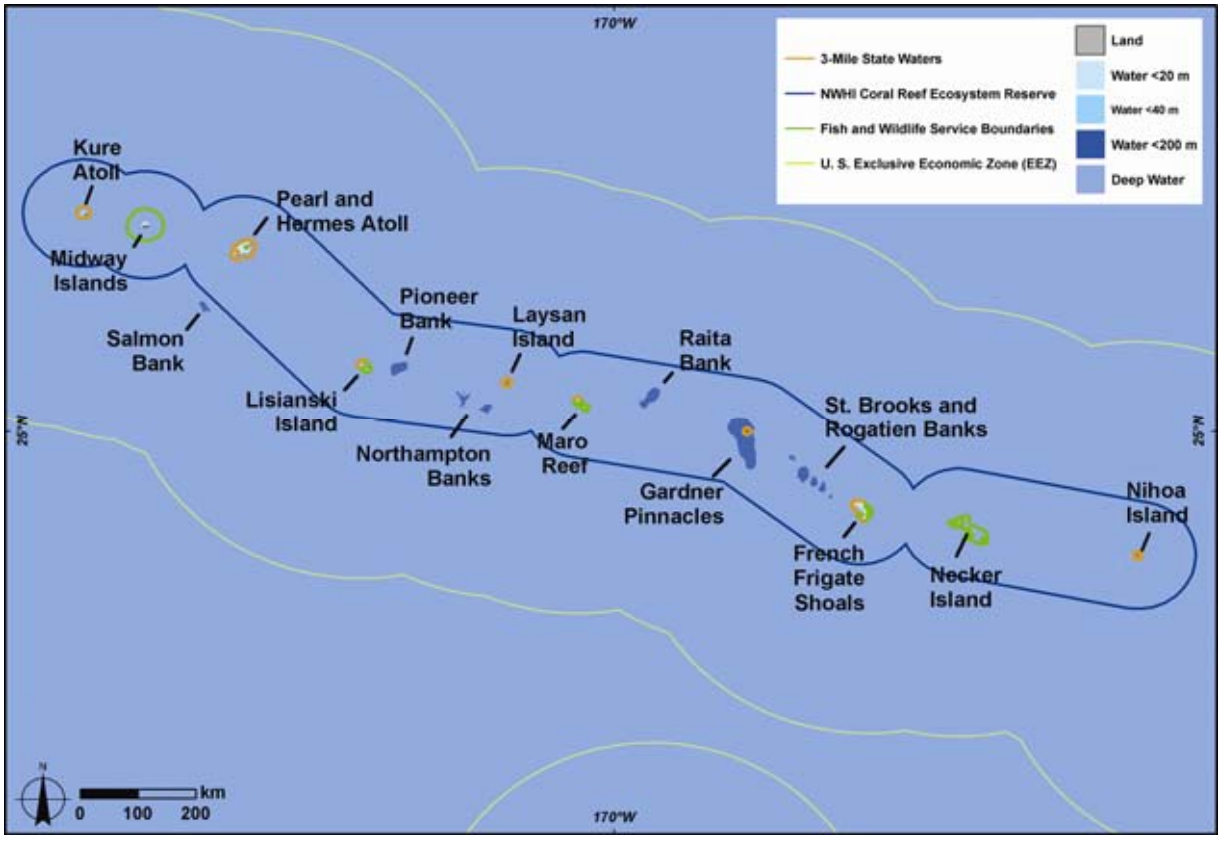


Figure 1. The Northwestern Hawaiian Islands, which extend across the north central Pacific, represent a vast, remote coral ecosystem that has been subjected to relatively minimal anthropogenic impacts. (Friedlander et al., 2005)

In an effort to provide further protection of the NWHI, NOAA was directed by Executive Order 13178 to initiate a process that would designate the NWHI Coral Reef Ecosystem Reserve (NWHI CRER) as a National Marine Sanctuary. The NWHI CRER is working with a multitude of partners to identify and address common management objectives. A major activity of NWHI CRER is the implementation and coordination of three integrated projects to support NWHI spatial data analysis and research. The three complementary studies are 1) a biogeographic assessment (this plan) led by NOAA's Biogeography Team (BT), 2) an evaluation and assessment of monitoring activities in the region led by the University of Miami, and 3) studies on connectivity, ecosystem condition, and coral health in the NWHI led by the University of Hawaii's Hawaii Institute of Marine Biology. In addition, NOAA Fisheries' Coral Reef Ecosystem Division (CRED) is an integral partner to these efforts as the group has collected many of the primary datasets of interest and currently archives most of the results of collaborative work undertaken in the NWHI; these data will be important for the initial phase of the NWHI spatial data analysis and research. Coordination of this suite of complementary projects will be accomplished through a series of meetings and by sharing of information and data across projects. For example, the NWHI CRER/ University of Miami study is developing a spatial framework to organize monitoring data sets and, where appropriate, this study domain will be used by the Biogeography Team to compile biogeographic data.

The biogeographic assessment has been designed to support NWHI CRER's scientific and management needs based on historical, recent, and planned research and monitoring studies within the NWHI. The assessment will result in a suite of spatially-articulated products for use by the NWHI CRER and its partners to support ecosystem-based management and the long-term, comprehensive protection and conservation of the marine resources of the NWHI. Results of this assessment will also help support the adaptive management process, identify gaps in information, and direct research priorities, while fulfilling stated goals related to developing effective collaborations and partnerships. Input was obtained from project partners of state, federal, and academic institutions and private sector partners to ensure its usefulness to regional issues and to minimize duplication of efforts.

PROJECT SUMMARY

Biogeography is the study of spatial and temporal distributions of organisms, their associated habitats, and the historical and biological factors that influence species' distributions. Defining biogeographic patterns of living resources found throughout the NWHI was identified as a priority activity at a May 2003 workshop designed to define scientific and management information needs for the NWHI. Thus, the Biogeography Team of NOAA's Center for Coastal Monitoring and Assessment (CCMA) and the NWHI CRER of NOAA's National Marine Sanctuary Program (NMSP) are designing and implementing a robust biogeographic assessment of the NWHI. This document should be viewed as a "living" project plan, as the projected tasks will be modified as necessary as the investigation evolves.

To support the NWHI CRER's efforts to develop an Environmental Impact Statement (EIS) for Sanctuary designation, the initial focus of this biogeographic study will be to provide technical support by characterizing areas of potential ecological significance and evaluating proposed management alternatives. Once the EIS has been finalized, focus will shift to address the major management objectives that have been articulated by the NWHI CRER. These include: 1) characterization of NWHI marine ecosystems and function, 2) identification of ecosystem-based management indicators to evaluate ecosystem health, and 3) evaluation of the effectiveness of zoning as a management tool for the NWHI.

The first product of the biogeographic assessment is this Project Plan which defines project objectives, specific tasks, and the planned product suite. Successful implementation of this project plan will require cooperation and participation with many federal, state, academic, and private sector partners. Without participation of key partners, such as NOAA's Pacific Islands Fisheries Science Center, Coral Reef Ecosystem Division (CRED), the University of Hawaii, the University of Miami, the State of Hawaii's Division of Aquatic Resources, and the U.S. Fish and Wildlife Service, the evolving investigation cannot meet project objectives.

The biogeographic assessment approach was developed by the Biogeography Team in consultation with the NMSP in 2003 (Kendall and Monaco 2003, Monaco et al. 2005). Sample products from previous biogeographic assessments are included as examples, where appropriate, later in this document. A completed biogeographic assessment and associated products can be viewed at: http://biogeo.nos.noaa.gov/products/canms_cd/).

Typically a biogeographic assessment is comprised of the three primary activities: 1) compile individual biogeographic data layers, 2) perform integrated biogeographic analyses, and 3) develop products to aid in management (Figure 2). A key tool used to develop and implement the assessment is the use of geographic information system (GIS) technology which aids in data compilation, spatial analyses, and visualization of results to support place-based management needs (Battista and Monaco, 2004).

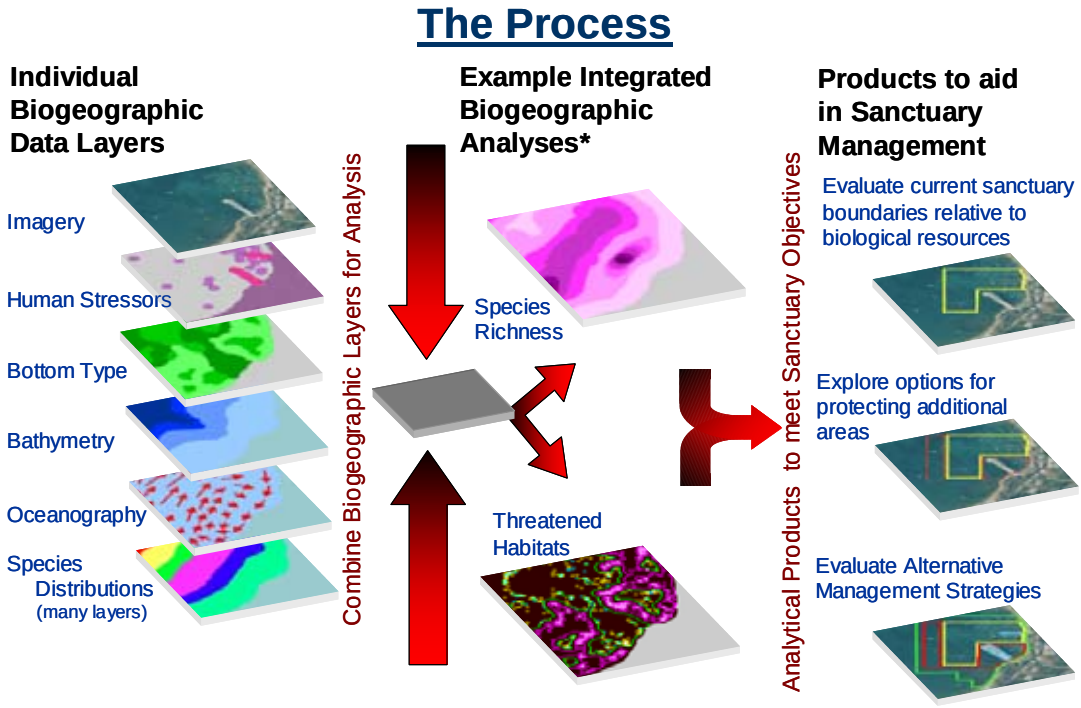


Figure 2. The biogeographic assessment process. (Kendall and Monaco, 2003)

The process shown in Figure 2 is based on geospatial and temporal analyses of existing physical and biological data and will result in many spatially-oriented products that will help managers better understand how the NWHI ecosystem functions. These analyses will aid in determining the strength of coupling between habitats and species and defining discrete areas of ecological significance (NOAA, 2003; Monaco et al., 2005). Potential uses of the biogeographic assessment include identifying and evaluating areas that are candidates for specific management approaches such as marine zoning, permitting, and targeted enforcement. For example, the Reserve has delineated draft boundaries for Sanctuary Preservation Areas (SPAs) and Ecological Reserves (ERs) to protect areas of high ecological significance to the Hawaiian archipelago. The results of the biogeographic assessment process will provide managers with the information needed to evaluate the efficacy of these zones.

Anticipated products and activities of this assessment include: 1) development of a robust marine geographic information system (GIS) for the area; 2) quantitative ecological analysis of resources in the study area (birds, mammals, fish, invertebrates, and habitats critical to those groups) to inform and support preferred zoning alternatives in the EIS; 3) determination of ecological linkages between habitats and biota to determine biodiversity "hotspots" and levels of ecosystem connectivity; 4) support for the development of a custom GIS tool to support Reserve/Sanctuary management for future analyses of biological resources under their purview; 5) identification of future research directions that will support and complement ongoing research activities underway by the NWHI CRER, the State of Hawaii, NOAA Fisheries, the University of Hawaii, and the U.S. Fish and Wildlife Service.

PROJECT OBJECTIVES

The biogeographic assessment of the NWHI will expand NWHI CRER's assessment capabilities and contribute greatly toward ecosystem-based management of the marine resources of the NWHI. The study is broad in scope and will include characterization of the physical and biological environments (e.g., oceanography, habitats) that structure the spatial and temporal distribution of living marine resources within and adjacent to the

Reserve/Sanctuary boundaries. Information on the distribution of living marine resources, including key species of interest identified by CRER staff, will be integrated with available biophysical information using various statistical and spatial analysis techniques to achieve the objectives stated below. Where possible, the study will integrate existing socioeconomic information related to NWHI fisheries (e.g., Ehler, 2003). Plans are to address the following major working objectives:

1. Identify and synthesize relevant biological, physical, and socioeconomic data sets for the study area. Organize the data in a common spatial framework within a Geographic Information System (GIS).

2. Conduct a marine biogeographic analysis of available data to identify important ecological linkages and ecologically significant regions and time periods, based on species distributions, abundance, associated habitats, and their ecological function.

3. Review zoning alternatives for the EIS in the context of biogeographic patterns observed in the seascape and identify areas of ecological significance.

4. Develop a GIS and spatial analysis capability that will assist CRER staff in evaluating future management actions.

5. Support CRER staff in the integration of biogeographic assessment products into the Sanctuary EIS process.

6. Identify gaps in existing data collection efforts and suggest appropriate research and monitoring activities to fill these data gaps.

7. Propose an approach for expanding the study area to the entire Hawaiian archipelago, which would involve the integration of biogeographic data and information for the main Hawaiian Islands.

To illustrate the capabilities that will be strengthened by the results of the biogeographic assessment, examples of expected products that address each of the above objectives are presented below. While some of the examples make use of recent data collected in the NWHI, many of the examples, especially those related to the analysis of species' distribution patterns, necessarily rely on work accomplished during other NMS biogeographic assessments. These are meant to serve as conceptual illustrations of the type of work undertaken during the process, and similar products will likely result from the biogeographic assessment of the NWHI. The examples of potential products to address specific project objectives presented below are then followed by a list of specific tasks that will be undertaken to meet the objectives and develop the associated products.

Objective 1. *Identify and synthesize relevant biological, physical, and socioeconomic data sets for the study area. Organize the data in a common spatial framework within a Geographic Information System (GIS).*

The first step in the biogeographic assessment process involves the identification and initial evaluation of data sets currently available for the study area. Although the data available for the NWHI study area may be less robust than for other biogeographic regions (e.g., the Southern California Bight), sufficient data sets exist to permit the identification of regions of importance to species, communities, and ecosystems both inside and outside of the study area (Figure 1).

Oceanography: Oceanographic information collected by CRED and others helps explain the role of currents in structuring the biotic community in the NWHI. Data provided by current profilers deployed throughout the NWHI over a 10-year period document the high variability of surface currents in the NWHI while confirming that the predominant flow of surface currents is from east to west (Figure 3). Similar information is available to describe oceanographic fluctuations over longer time scales, including those related to phenomena like El Niño/ La Niña and the Pacific Decadal Oscillation.

Oceanographic data is an important determinant of the structure of many marine ecosystems and species distribution patterns. In the NWHI it is of particular interest because of the influence of currents on dispersal of larvae throughout the archipelago. The level and nature of connectivity between the main and NWHI is not well understood and is of great interest to the CRER and the State of Hawaii.

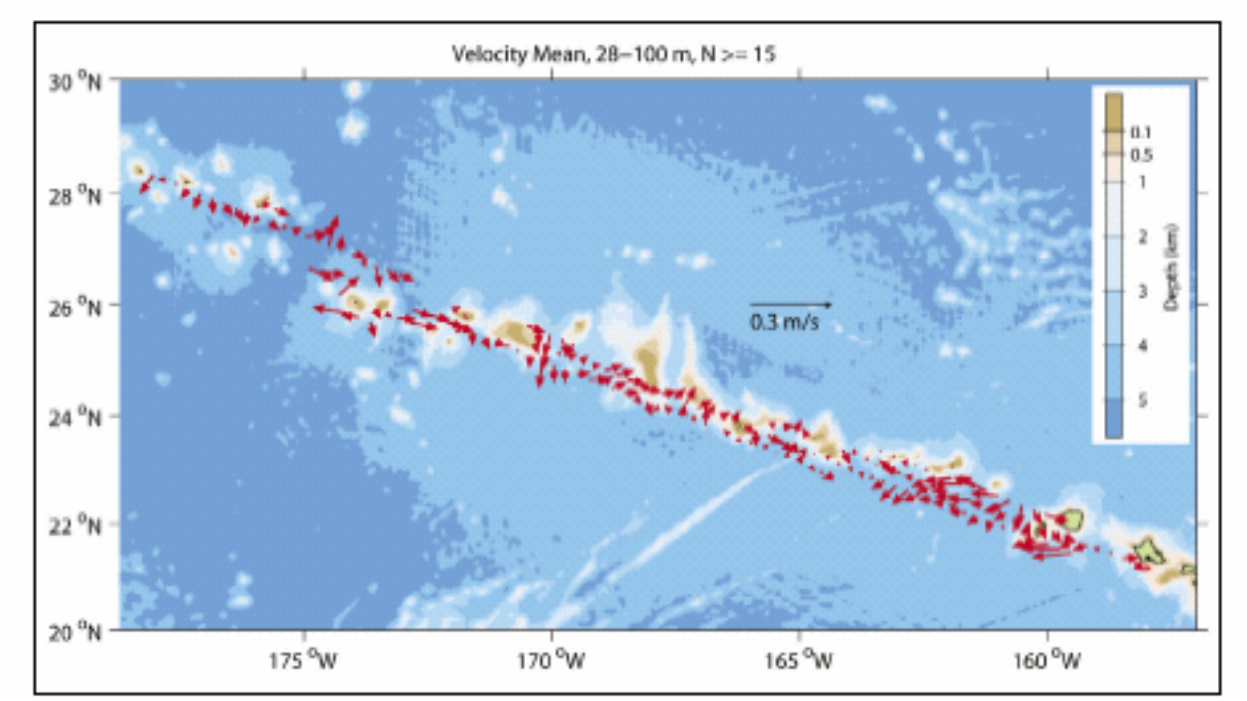


Figure 3. ADCP data from 1990 to 2000 averaged over time. The upper ocean currents in the NWHI are highly variable in both speed and direction, being dominated by eddy variability. The resultant mean flow of surface waters tends to flow predominantly from east to west in response to the prevailing northeast tradewinds. (Friedlander et al., 2005).

Bathymetry: Another primary physical determinant of biological community structure relates to the bathymetric variance of the seafloor. Fine scale rugosity and bathymetry have been identified as one of the most important factors structuring the distribution of living marine resources, especially for organisms associated with the benthos (Friedlander and Parrish, 1998; Friedlander et al., 2003). Detailed bathymetric information, while incomplete for the entire study area, is available for some areas (Figure 4) and will be incorporated into the proposed biogeographic assessment.

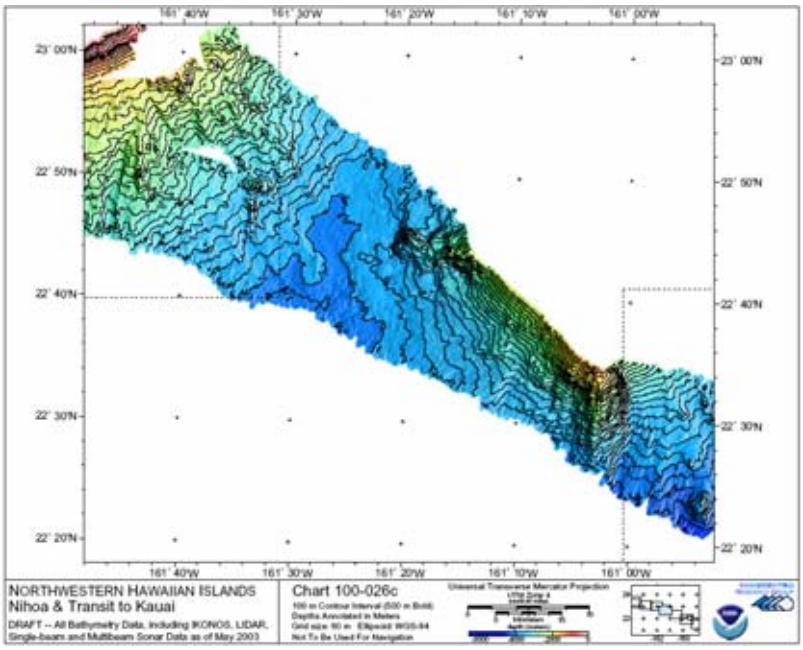


Figure 4. An example of a relatively fine-scale draft bathymetric map of portions of the seafloor between Nihoa and Kauai developed by CRED. (Miller et al., 2003)

Benthic Habitats: Because many species are strongly associated with particular habitat types, the use of benthic habitat maps developed by NOAA and published in 2003 (Figure 5) will be essential to the project (NOAA, 2003a). Other features of the benthos in the NWHI, such as distribution maps for the 6 most dominant algal species developed by CRED will also be used. Although such products are fairly coarse, they will be useful in large-scale modeling activities.

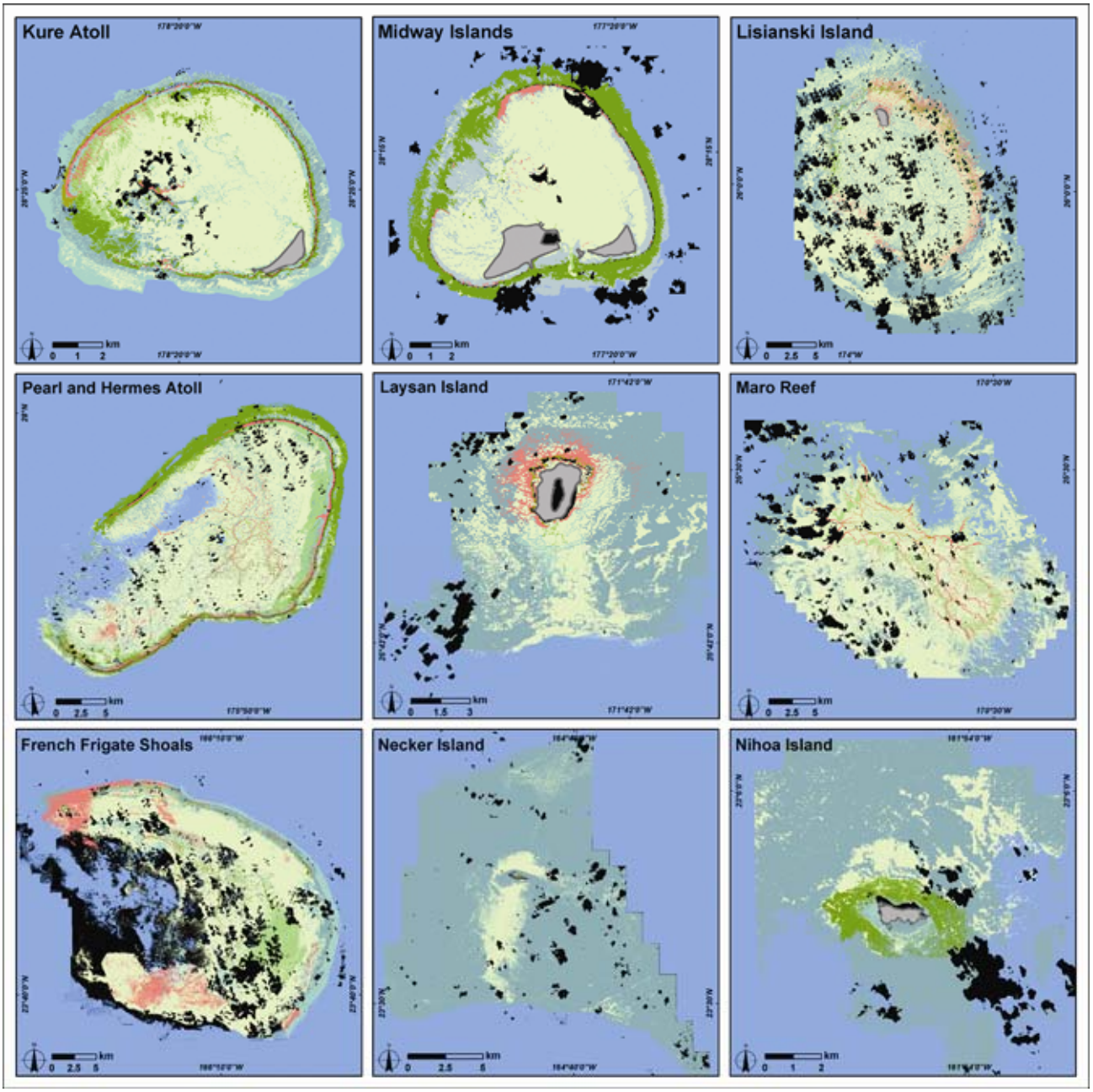


Figure 5. Draft nearshore benthic habitat maps were developed for the NWHI by NOAA, based on supervised classification of IKONOS satellite imagery. (NOAA, 2003a)

Coral Endemism: Endemism is a major determinant of the uniqueness of a biological community, and protection of endemic species is of primary importance to the conservation of global marine biodiversity. Coral endemism is high in the NWHI (Maragos et al., 2004). Surveys conducted between 2000 and 2002 recorded 17 endemic species (30%), which accounted for 37-53% of the relative abundance of stony corals. In terms of percent live coral cover, surveys conducted in 2002 revealed that percent live coral cover varies greatly among the NWHI (Figure 6). While most of the NWHI had low coral cover, Maro Reef and Lisianski had comparatively high coral cover (Friedlander et al., 2005).

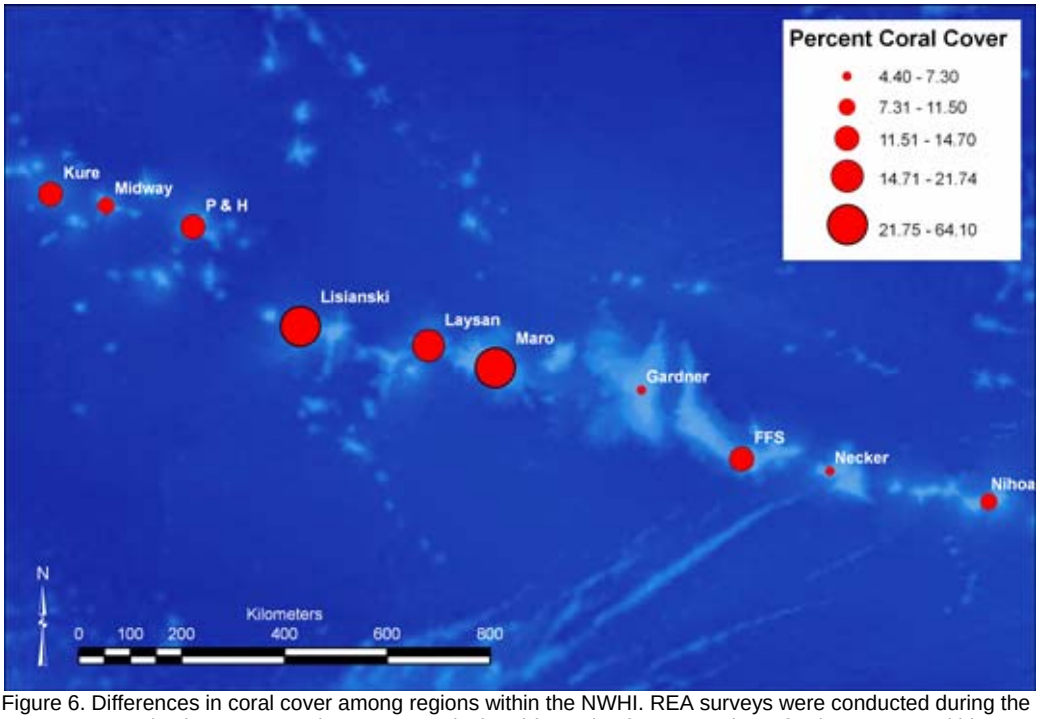


Figure 6. Differences in coral cover among regions within the NWHI. REA surveys were conducted during the NOWRAMP cruise in 2002. Coral cover was calculated from size frequency data of colony counts within transects. Source: Friedlander et al., 2005.

Marine Mammals: Investigations of marine mammals along the U.S. west coast conducted by NOAA Fisheries' SWFSC yield another example look at areas of biological importance in relation to the presence of marine mammals. In this example, blue whale sightings are plotted in conjunction with effort data to illustrate seasonal patterns in density and the effect of large scale oceanographic fluctuations on distribution patterns. While data on whales and cetaceans in the NWHI may be somewhat limited, there is a large body of work focused on the endangered Hawaiian Monk Seal. Areas of importance to these and other protected species should factor in to management decisions made by CRER staff. Knowing the location of important areas, such as haulouts, rookeries, primary foraging grounds, and other high use areas, and the temporal patterns associated with their use will help managers mitigate potential impacts from proposed or future activities.

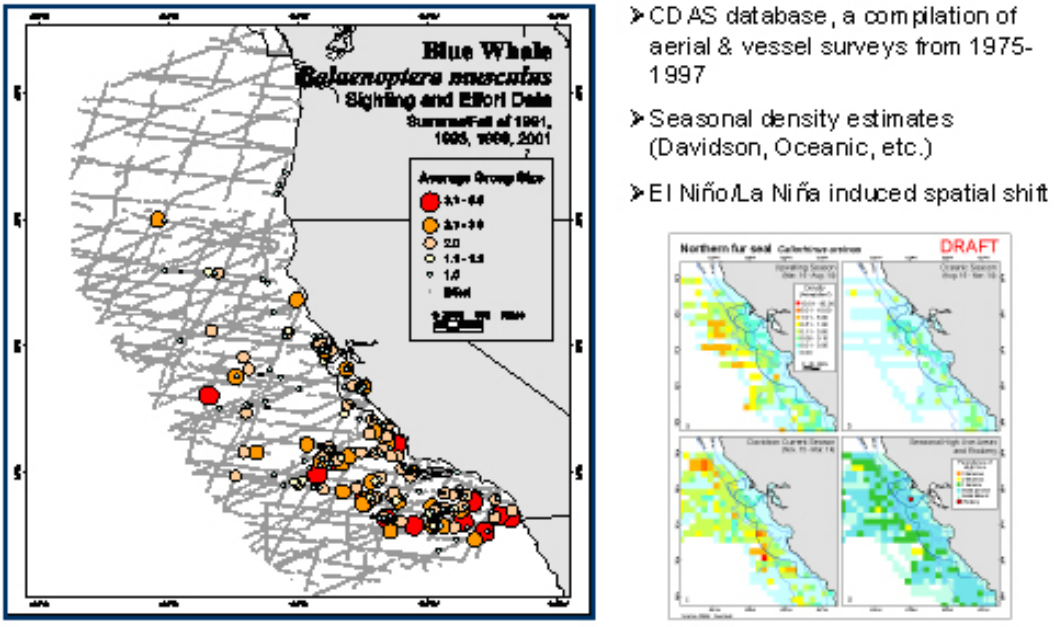
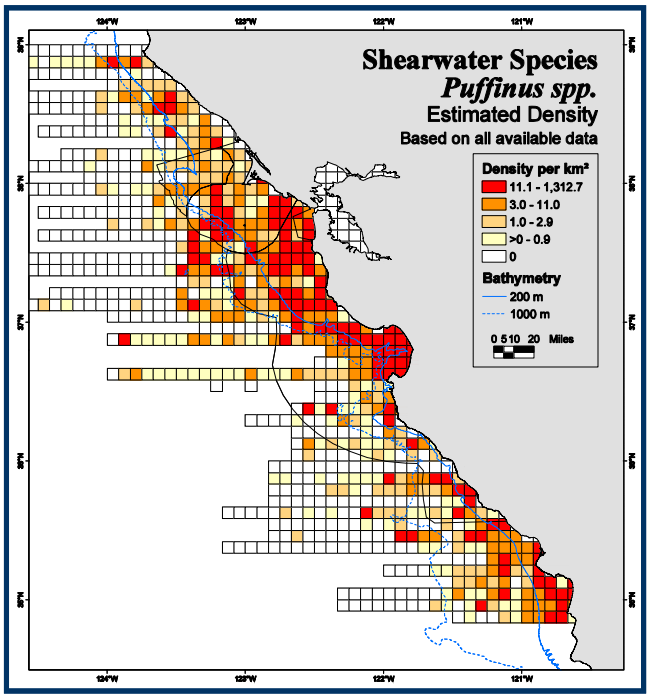


Figure 7. Spatial and temporal analyses of effort and presence data for blue whales recorded during aerial and ship-based surveys conducted along the U.S. west coast. Seasonal use data for Northern Fur Seals as documented by the CDAS data set. (NOAA, 2003b)

Similarly, data collected on the distribution of various species of seabirds can indicate areas of importance to particular species for foraging and nesting. Synthesis of multiple data layers for seabird species helps identify regions of high biological productivity for the ecosystem as a whole. Such analyses provide scientific justification for greater protection of critical habitats.

The left panel of Figure 8 illustrates the density of multiple species of Shearwater along the central California coast as an annual aggregate. The panel on the right shows the diversity of birds along the coast, illustrating the importance of upwelling at the shelf break to many species of seabirds. During all seasons, a large number of seabird species utilize the productive region near the shelf break, and according to the data collected over the past 20+ years, use seems particularly concentrated near the Farallon Islands during the Oceanic period that occurs during late summer and fall. The identification of important biological areas outside current boundaries may have implications for future management directions.



- CDAS database, a compilation of aerial & vessel surveys from 1975-1997
- Seasonal density estimates (Davidson, Oceanic, etc.)
- El Niño/La Niña induced spatial shift
- Measures of bird community structure (Richness, Diversity)

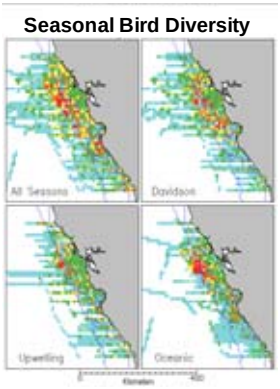


Figure 8. Spatial and temporal analyses of effort and presence data for shearwater species recorded during aerial and ship-based surveys conducted along the U.S. west coast. (NOAA, 2003b)

Objective 2. *Conduct a marine biogeographic analysis of available data to identify important ecological linkages and ecologically significant regions and time periods, based on species distributions, abundance, associated habitats, and their ecological function.*

The biogeographic assessment process will use overlays of multiple data layers to investigate important ecological linkages between species and habitats and, where possible, identify temporal differences in species distributions. A few examples of known linkage patterns are presented below. For example, Figure 9 uses data collected in the NWHI by CRED and BT to depict the relative level of endemism recorded at each of the NWHI based on fish transect surveys conducted during research cruises from 2000 to 2002. The endemism of fishes based on numerical densities in the NWHI is the highest reported for any tropical marine ecosystem on earth and distinguishes the area as a global biodiversity hotspot. Endemism is highest at the northern portion of the archipelago. Coupling this information with data on fish recruitment patterns and oceanography suggests greater retention of larvae within the northern islands, a possibility that could be important for management across the entire archipelago.

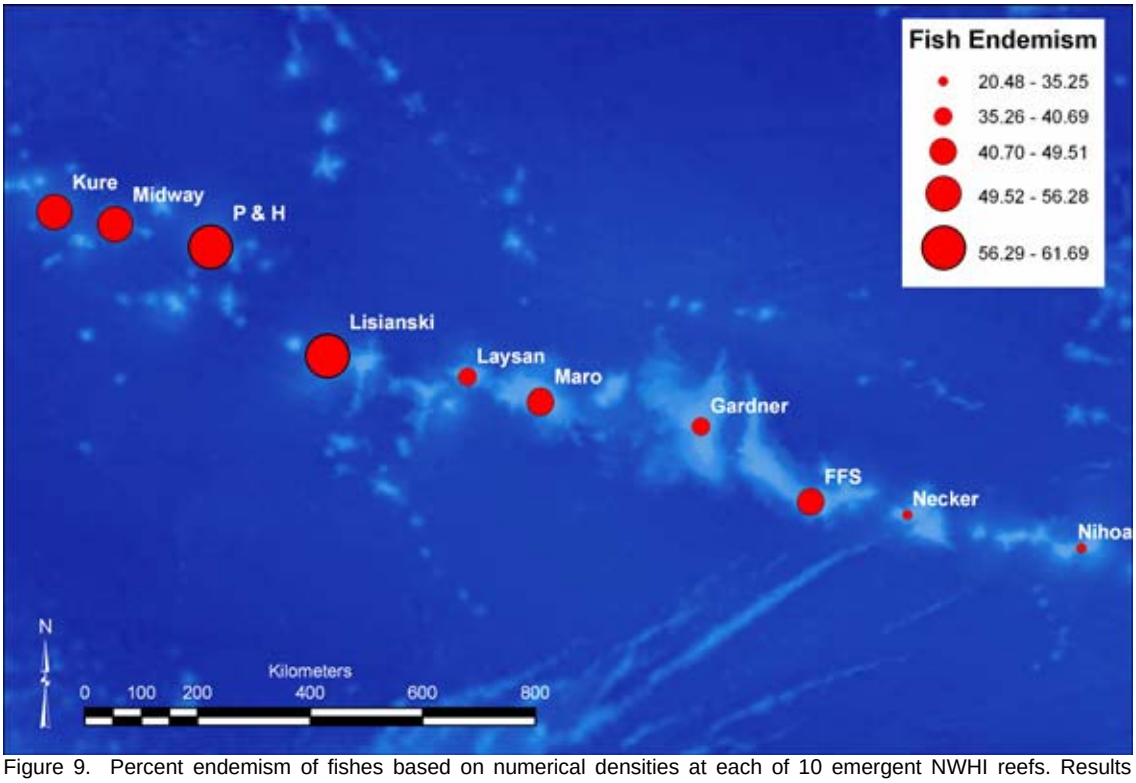


Figure 9. Percent endemism of fishes based on numerical densities at each of 10 emergent NWHI reefs. Results clearly indicate that endemism is highest at the northern portion of the archipelago. Adapted from DeMartini and Friedlander, 2004.

To identify biologically important areas, our experiences in past biogeographic assessments have relied on both the availability of robust data and modeling techniques that attempt to fill data gaps through the use of highly-sophisticated, scientifically defensible geo-spatial modeling techniques (including surface interpolation, spatial autocorrelation, etc.). In the absence of comprehensive and robust data sets, modeled results may represent the best available information. Once the analysis of existing data for the NWHI is underway, biologically meaningful and statistically significant patterns in the distribution of marine fauna and flora will emerge and can be further investigated. Based on the data collected, the biogeographic assessment will also investigate the persistence of spatial patterns over time, the co-location of taxonomic hotspots, and the significance of patterns and places over time within a broader biogeographic context.

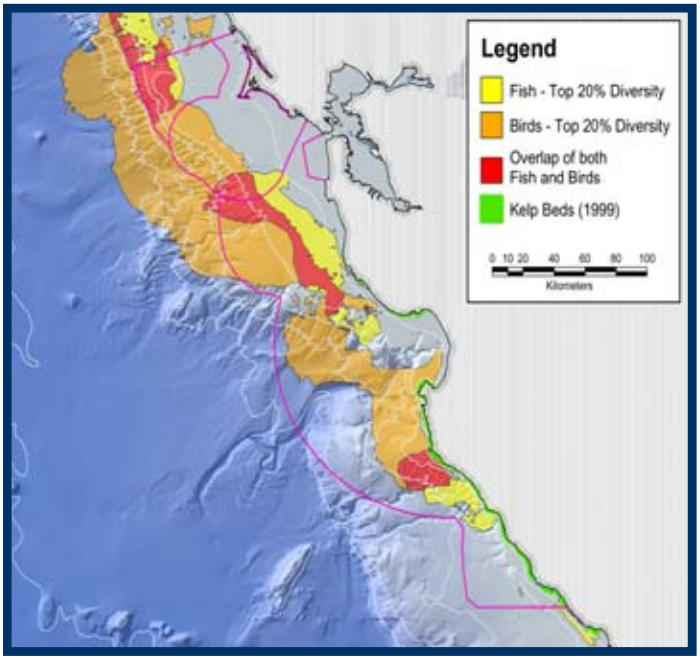


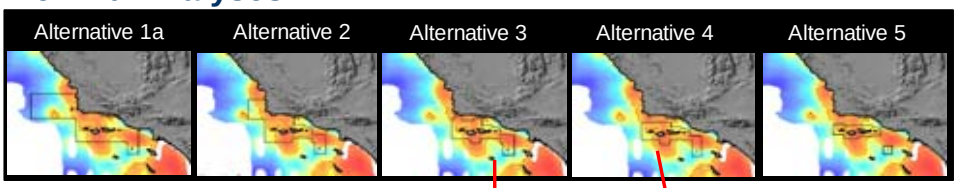
Figure 10. A map product of the integration of various species layers that depicts areas of high diversity for multiple taxa and the distribution of kelp habitat along the central California coast. (NOAA, 2003b)

Figure 10 represents one method for integrating empirical and modeled data on the diversity of fish and bird communities along the central California coast. Overlay of these data layers identifies locations where highly diverse communities of both taxa exist. Depending on the stated management priorities of each Sanctuary, a variety of options for data representation are available, ranging from single-species distribution maps to landscape-scale portrayals of multiple species groups and physiographic layers, all of which can be depicted using tools developed during the biogeographic assessment process.

Objective 3. *Review zoning alternatives for the EIS in the context of biogeographic patterns observed in the seascape and identify areas of ecological significance.*

Once the suite of primary physical and biological data layers have been assembled and integrated, various spatial analytical techniques can be applied for the purposes of evaluating management alternatives, especially place-based management approaches such as zoning or boundary evaluation. In the Channel Islands NMS, six different alternative boundary proposals were evaluated in relation to their predicted impact on various species assemblages. Figure 11 uses a concept called the Optimal Area Index to demonstrate the increase in protection for marine birds from boundary modification while taking into account the change in area (from the current boundaries) that would be encompassed by each boundary alternative. In this way, managers can easily grasp the potential value of proposed boundary modifications to various taxa from a spatial perspective.

Marine Bird Analyses



OAI represents the relative increase in ecological metric for alternative, divided by the relative increase in area compared to current boundaries

Alternative	Area (km^2)	Mean Bird Diversity	High Diversity Area (km^2)	Δ Area (%)	Δ Mean Diversity (%)	Δ High Diversity Area (%)	Mean Bird Diversity OAI (relative)	High Diversity Area OAI (absolute)
NAA	3745	1.485	2284	-	-	-	-	-
5	4536	1.487	2812	21	0.13	23.12	0.00638	1.094
4	7981	1.523	5507	113	2.56	141.11	0.02262	1.249
3	9044	1.53	6421	141	3.03	181.13	0.02141	1.28
2	13736	1.502	8791	267	1.14	284.89	0.00429	1.068
1a	22591	1.372	10391	503	-7.61	354.95	-0.01512	0.705
1	22613	1.375	10401	504	-7.41	355.39	-0.0147	0.705
SA	17093	1.489	9914	356	0.27	334.06	0.00076	0.937

$$\text{Optimal Area Index (OAI)} = \frac{(B_1 - B_0/B_0)}{(A_1 - A_0/A_0)}$$

B_1 and B_0 are the value of the ecological metric (e.g. sightings, diversity, richness, etc.) within the boundary alternative and the current boundaries respectively, and A_1 and A_0 are the respective areas.

Figure 11. An analysis of the potential value of boundary alternatives for the Channel Islands NMS in relation to their benefit for conservation of marine bird species. (NOAA, 2005)

During the EIS process for Sanctuary designation, various alternatives and a preferred alternative will be identified. Although the biogeographic assessment process will not be complete by the time the Final EIS is due, interim products of the biogeographic assessment can be used to help weigh the costs and benefits of each proposed option and provide a scientific basis for support of the preferred alternative. Once completed, the biogeographic assessment's primary utility will be in addressing emerging issues, supporting management decisions, and evaluating management actions, particularly in the context of the NMSP's 5-year management plan review process.

Objective 4. *Develop a GIS and spatial analysis capability that will assist CRER staff in evaluating future management actions.*

Though it is difficult to predict management issues that are likely to emerge in the future, the biogeographic assessment will enable managers to respond to possible future challenges such as the spread of alien species, ship groundings, disturbance from tourism and research activities, and concerns about threatened and endangered species. For example, coupling layers depicting the distribution of habitats and prevailing currents with potential introduction vectors could help managers identify key monitoring areas for early detection of alien invasive species introductions. Eradicating such invaders before they become fully established will help maintain the integrity of the NWHI ecosystem.

Objective 5. *Support CRER staff in the integration of biogeographic assessment products into the Sanctuary EIS process.*

The EIS process for Sanctuary designation will produce an evaluation of various alternatives related to management of the NWHI. Staff engaged in the biogeographic assessment process will participate in the production of the Final EIS by providing advice and preliminary products from the biogeographic assessment to the Reserve staff. In this way, the selection of a preferred alternative will be supported by analysis of the best information currently available.

The approach for evaluating boundary alternatives may be similar to the evaluation of boundary options conducted as part of the biogeographic assessment for the Channel Islands NMS (Figure 12). In the Channel Islands, five alternative boundary options and a 'no action' alternative were evaluated based on physical and biological data layers assembled as part of the biogeographic assessment process, enabling decisions based on the biological character of the region and informed by socio-economic and political realities. A similar effort directed at the NWHI would help the CRER staff move toward ecosystem-based management of the region while allowing for input from those potentially affected by management actions.

The sanctuary's management plan review process has identified five alternatives, plus a 'no action' alternative for consideration as boundary modifications.

These proposed boundaries would encompass areas ranging from 3,745 km^2 to 22,613 km^2.

The six proposed boundary alternatives were integrated.

Only one set of analyses contributing to boundary modification discussion (e.g. socioeconomic, political)

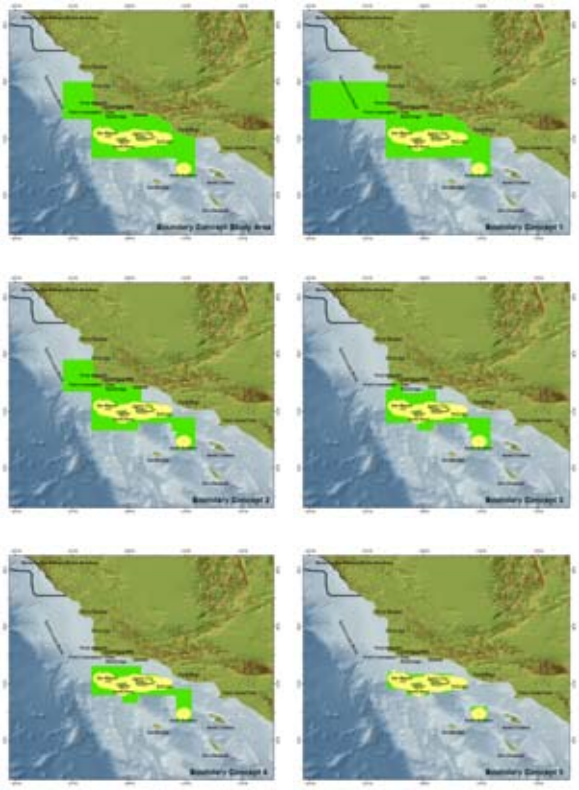


Figure 12. Analysis of proposed alternative boundary options explored in the biogeographic assessment for the Channel Islands NMS. (NOAA, 2005)

Objective 6. *Identify gaps in existing data collection efforts and suggest appropriate research and monitoring activities to fill these data gaps.*

The products of the biogeographic assessment and the associated collaborative activities with the Universities of Miami and Hawaii will help identify shortcomings in current monitoring efforts and will permit managers to target priority activities based on current and emerging management issues. This will likely include suggestions about how to flesh out research and monitoring activities to better capture temporal variations in biological community composition and distribution, supplement ongoing monitoring activities to better respond to emerging issues such as coral bleaching and alien species introductions, improve experimental designs through stratification of sampling design based on various physical parameters (exposure, habitats, zones, etc.), and improving large-scale modeling efforts.

Figure 13 demonstrates how monitoring data of fish diversity in discrete locations can be used to create a predictive surface for diversity on a landscape scale. In this case, subsequent monitoring efforts in the region can be used to validate and refine the modeling exercise and thereby produce more reliable predictive models of the region. Such efforts will be particularly helpful in the NWHI, where modeling is necessary because of a lack of spatially and temporally comprehensive data for some of the less well-studied banks and islands.

Results: Southwestern Puerto Rico

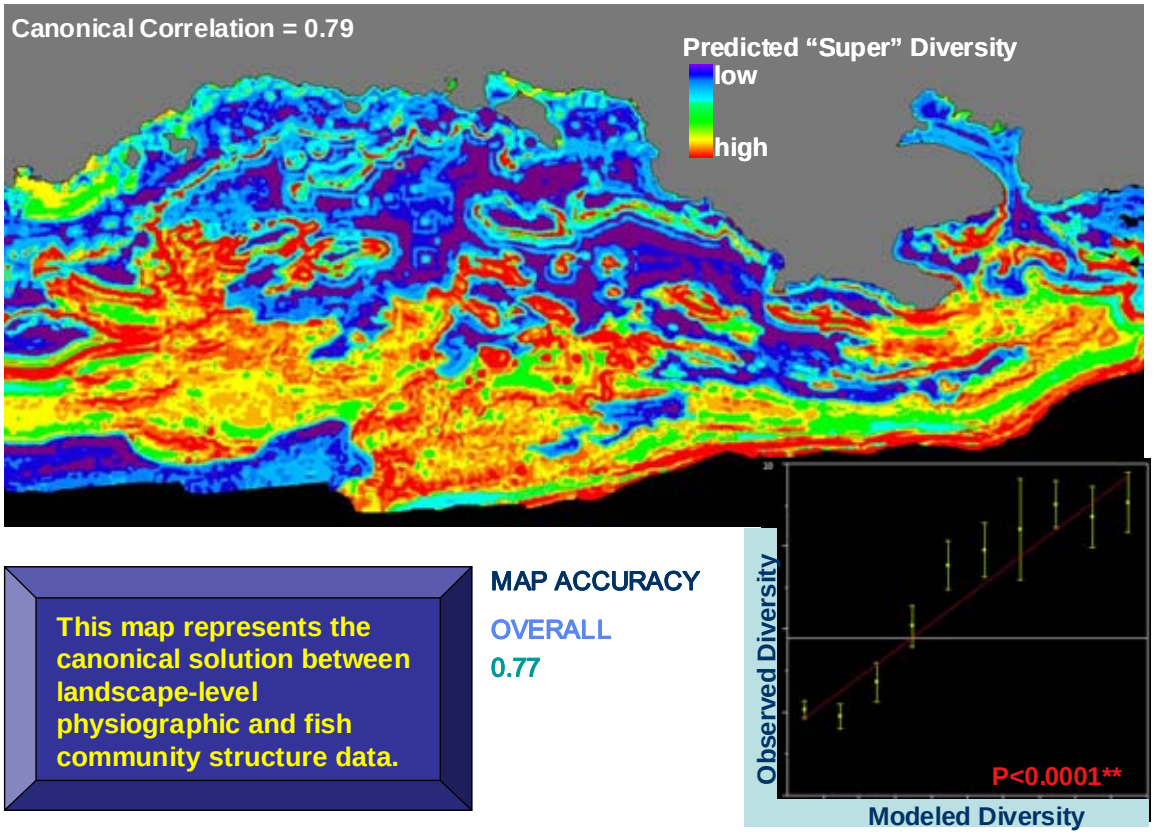


Figure 13. A predictive surface showing areas of high fish diversity (warm colors) in the nearshore coral reef ecosystem near La Parguera, Puerto Rico. (Christensen et al., in prep).

Objective 7. *Propose an approach for expanding the study area to the entire Hawaiian archipelago, which would involve the integration of biogeographic data and information for the main Hawaiian Islands*.

The final task associated with this work will be to evaluate the products of the biogeographic assessment for the Northwestern Hawaiian Islands and propose an approach for expanding the study area to include the entire Hawaiian archipelago. Because the main Hawaiian Islands have been studied more extensively than the NWHI, the incorporation of data from the Main Hawaiian Islands may illuminate landscape scale issues of importance to the region as a whole, such as the extent of interconnectedness between various regions of the island chain. Regional scale biogeographic assessments, such as the one recently initiated for the U.S. west coast, will help guide efforts to establish effective networks of marine protected areas, including Sanctuaries, and thereby conserve and protect coastal and ocean habitats and species.

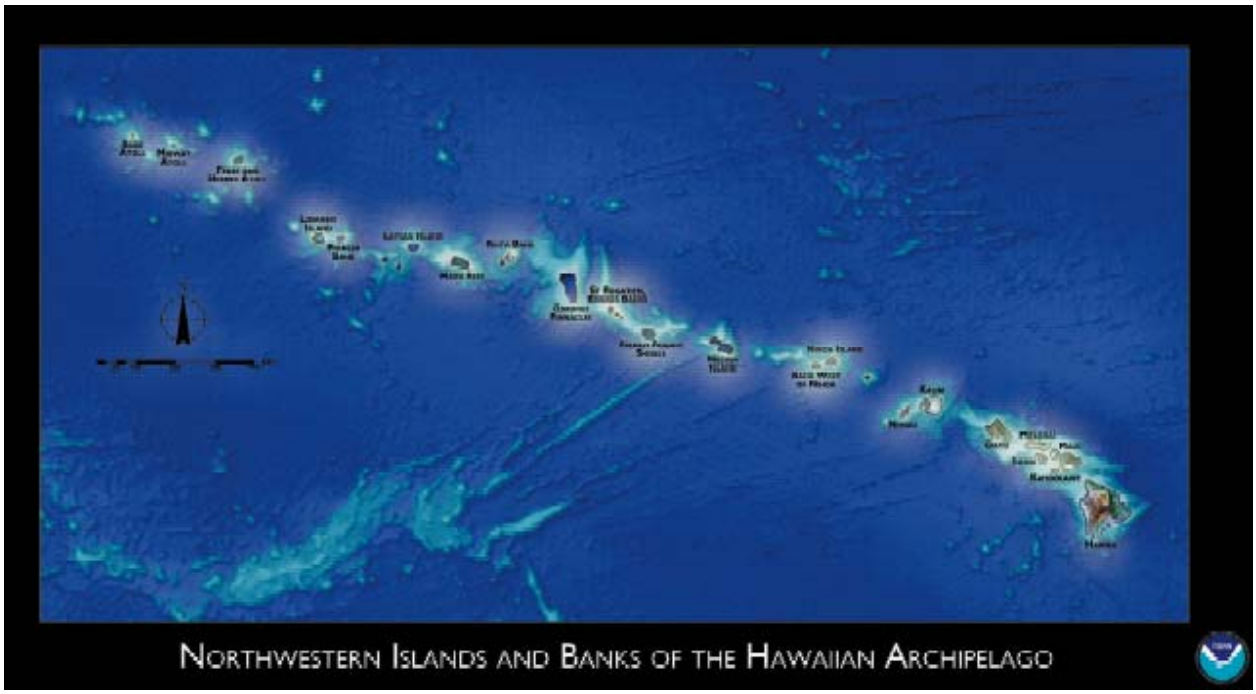


Figure 14**.** The Northwestern Hawaiian Islands, which extend across the north central Pacific, represent a vast, remote coral ecosystem that has been subjected to relatively minimal anthropogenic impacts.

PROJECT TASKS

Below are brief descriptions of the major tasks planned for this biogeographic assessment to address study objectives and questions. Please refer to Figure 2 for a diagram of the proposed process and schedule for completing the assessment.

Task 1. Project Plan Development
(Estimated Completion Date: December 2005)

There will be several meetings with BT, NMSP HQ, and NWHI CRER staff to refine the objectives, tasks, and products in the work plan. As such, this workplan should be considered a "living document" that will be modified during the early phases of this project to reflect the agreed upon refinements. This work plan will describe the overall project and serve as a blueprint for implementation. Although specific products are identified in this work plan, final products will depend on the quality, quantity, and availability of data for analysis. Hence, close collaboration with NWHI CRER and NMSP staff will be required to ensure the Biogeography staff is well-informed on the resource management priorities and alternatives under consideration by NMSP. Effective two-way communication is essential to assure that the analytical team has selected the most appropriate species, habitat types, and data sets for analysis. Once the preliminary objectives and products are defined and finalized, data collection and biogeographic analyses (described below) will be structured to address the study objectives.

Task 1 Products:

- A completed, reviewed draft of the project plan

Task 2. Initial Data Collection
(Estimated Completion Date: June 2006)

The primary path for identifying relevant data sets for biogeographic analysis will be through consultation with Reserve staff and other regional experts and through meetings as described in Task 3. Alan Friedlander, the project lead for BT, is intimately familiar with many of the researchers and data sets relevant to the project and study area which will greatly facilitate this task. To a lesser extent, data also will be collected through searches of peer reviewed literature, internet offerings, and review of unpublished data (e.g. gray literature). Physiographic data on bathymetry, oceanography, habitats and other parameters of the physical environment will form a fundamental backdrop for the study of species distribution patterns. Major species groups to be studied will likely include marine fishes, invertebrates, sea birds, marine mammals, and marine reptiles found throughout the study area. The synthesis of biological and physical environmental data will aid in developing a robust ecosystem assessment based on the principles of biogeography.

Task 2 Products:

- List of contacts (task 3)
- Preliminary data inventory (master list)

Task 3. Additional Data Collection
(Estimated Completion Date: July 2006)

To ensure the project stays on task and meets the NWHI CRER scientific and management requirements, a suite of project status meetings will be held. In addition, the data mined in Task 2 will be evaluated and if necessary additional data collection efforts will be conducted. Task 3 will also provide an initial assessment of data needs and information gaps which can help the CRER prioritize future data collection efforts.

NWHI CRER is sponsoring a meeting in April 2006 to convene local experts in the study region to discuss projects currently ongoing in and around the NWHI. An initial data review meeting prior to the April workshop is tentatively scheduled for February 2006. BT staff will attend these meetings to gather any additional biological and/or oceanographic data that may prove useful for the project.

Task 3 Tasks/Products:

- Attend February meeting in Hawaii
- Attend April monitoring meeting in Hawaii
- Develop inventory of newly acquired data and contacts
- Develop inventory of gaps in biogeographic data sets for the NWHI

Task 4. Data Assessment, Formatting, and Selection of Analytical Techniques
(Estimated Completion Date: January 2007

The NWHI CRER is in the process of developing a comprehensive and integrated information management system (IMS) that will be prototyped during the course of this project. Once data sets are obtained they will be formatted and organized into a preliminary database management system (DBMS) and GIS to assess their quality and content. To the extent possible, the DBMS will be developed consistent with the NWHI CRER's prototype IMS for future integration. All data acquired and used for the assessment will be standardized by BT and University of Miami staff into a common spatial projection. BT/Miami staff will consult with NWHI CRER staff on the preferred projection and datum. As data are standardized, BT staff will make them available through a project website in accordance with the limitations (if any) imposed by the source of the data (see Task 9). This will allow NWHI CRER staff and other interested scientists access to a significant volume of spatial data for quick and easy use throughout the duration of the project.

With the DBMS and GIS in place, BT staff will evaluate and select the most appropriate techniques to use in the analyses. At the same time, staff will determine if and where independent biological and physical databases can be integrated or synthesized into more spatially comprehensive datasets to support the biogeographic analyses. Figure 2 (page 5) shows the general analytical process that will be implemented. The analyses may range from simple presence/absence of species within a grid cell framework to complex statistical analyses, such as canonical correlation analysis to define spatial relationships between animal distributions and habitats (Figure 13). The variety and limitations of the various data sets are expected to have a major influence on the character of the biogeographic analyses. A preliminary approach to analysis will be presented to Reserve/Sanctuary and project partners for comment and approval. Once the optimal approach to analysis and data manipulation has been identified, all data will be migrated into the appropriate DBMS and GIS format to conduct the biogeographic assessment.

Task 4 Products:

- A brief report and presentation describing the preliminary data collection and assessment.
- Standardized spatial data compendium (DBMS-GIS)

Task 5. Geospatial and Ecological Data Analyses
(Estimated Completion Date: July 2007)

The BT staff will conduct a set of biogeographic analyses to identify areas (and time periods) of key biological importance based on: species distributions (actual and modeled); species life history requirements and habitat affinities; distribution of habitats; and standard measures of community structure (e.g., species diversity). The complexity of these analyses will depend on the content, quality, and comprehensiveness of the data sets available. Once a series of comprehensive spatial analyses have been performed, results will be "sampled" into each of the zoning alternatives. Statistical comparisons will be made to evaluate the relative "cost/benefit" of each management zone to biological resources in the study area. This will include a discussion of parameter estimates "included" in one zone relative to another, and to areas outside the specific zone, but still inside the overall study area. Where data permits, these analyses shall be performed for fishes, invertebrates, birds, mammals, and habitat features (e.g., bathymetry, temperature profiles, currents, etc.). Furthermore, all data will be integrated into a spatially-articulated index in an attempt to evaluate overall spatial patterns. This index will be defined after a complete inventory of the available data has been assembled. An example index might include an integrated spatial estimate of ecological "hot spots" using parameters of community structure for multiple taxa (e.g., species diversity and evenness for birds, fishes, mammals, etc.). For example of an index developed to define ecologically significant areas, please see the 'Optimal Area Index' developed during the biogeographic assessment of the Channel Islands National Marine Sanctuary (NOAA, 2005), located at: http://biogeo.nos.noaa.gov/projects/assess/ca_nms/cinms.

Task 5 Products:

- Quantitative and qualitative assessments that identify biogeographic patterns and bio-physical interrelationships of single species, species assemblages, and measures of community structure within the study area
- Quantitative and qualitative assessments describing the physical and oceanographic setting within the study area (e.g., acreage of habitat, distribution of bathymetric estimates, substrate distributions, etc.)
- Comparisons of the above results in the context of proposed management alternatives

Task 6. Interim Review Products
(Estimated Completion Date: November 2007)

Draft species, habitat, and analysis maps (e.g. species richness, diversity) coupled with statistical results will be made available to NWHI CRER staff, project partners, interested members of the RAC, and other experts for review in a workshop format. In addition, a report will be developed that provides interpretation of the results of the biogeographic GIS-based analyses that can be easily integrated into the management plans. A list of specific questions and comments will be provided to reviewers to obtain feedback on specific areas of the analysis.

Task 6 Products:

- Interim analytical results (maps, statistical results) from the biogeographic GIS (workshop)
- A database on habitat affinities and utilization for selected species
- Comparisons of results among zoning alternatives
- A list of comments and questions for reviewers
- A map and/or list of data gaps
- A brief status report

Task 7. Incorporate Review Comments & Development of Final Digital Products
(Estimated Completion Date: December 2007

Once products have been reviewed by selected NWHI CRER/NMSP staff and other experts, the BT staff will incorporate review comments and prepare final products in an appropriate format for inclusion in supplements to the NWHI CRER or Sanctuary management plan.

Task 7 Products:

- A final summary report describing the analysis, results, and interpretation of the results
- A GIS on species, habitats, and important biological areas in the study area
- A DBMS with data and information on species and habitats
- A map and/or list of data gaps

Task 8. Scoping Report on the Potential to Integrate NHWI Biogeographic Assessment with the Main Hawaiian Islands for Archipelago-wide Assessment.
(Estimated Completion Date: September 2008)

At the completion of the project, partners will meet to determine the feasibility of developing and biogeographic assessment for the main Hawaiian Islands and integrating into the NWHI assessment to provide an archipelago-wide biogeographic assessment.

Task 8 Products:

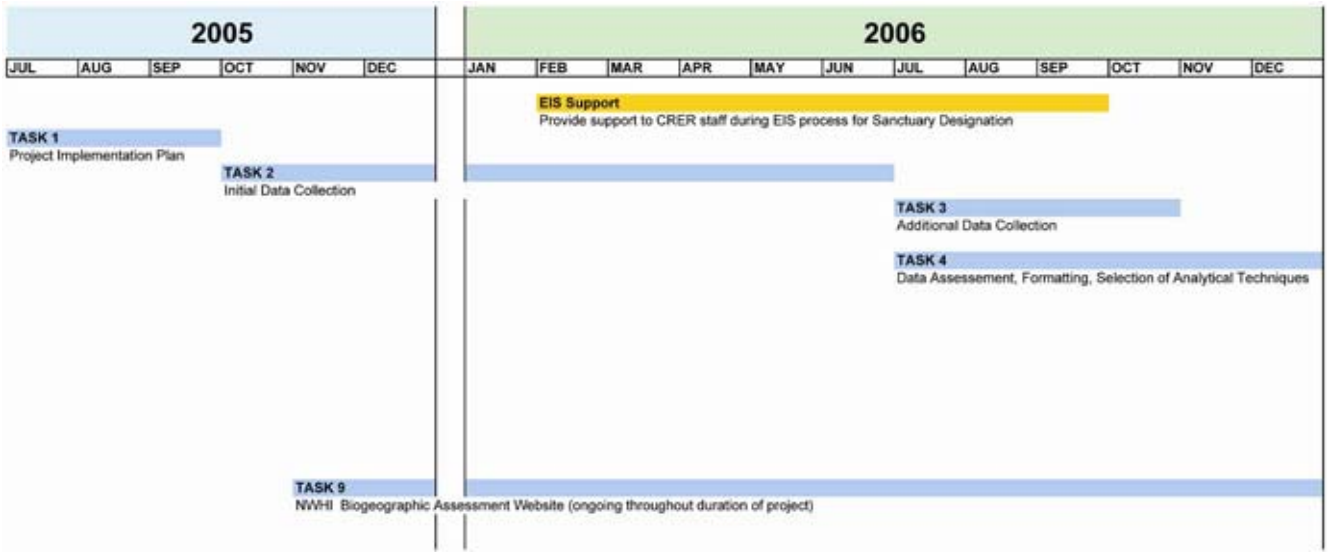
- A set of recommendations on the feasibility and utility of expanding the biogeographic assessment into the main Hawaiian Islands based on many factors including data availability, funding, and relevance to management agencies.

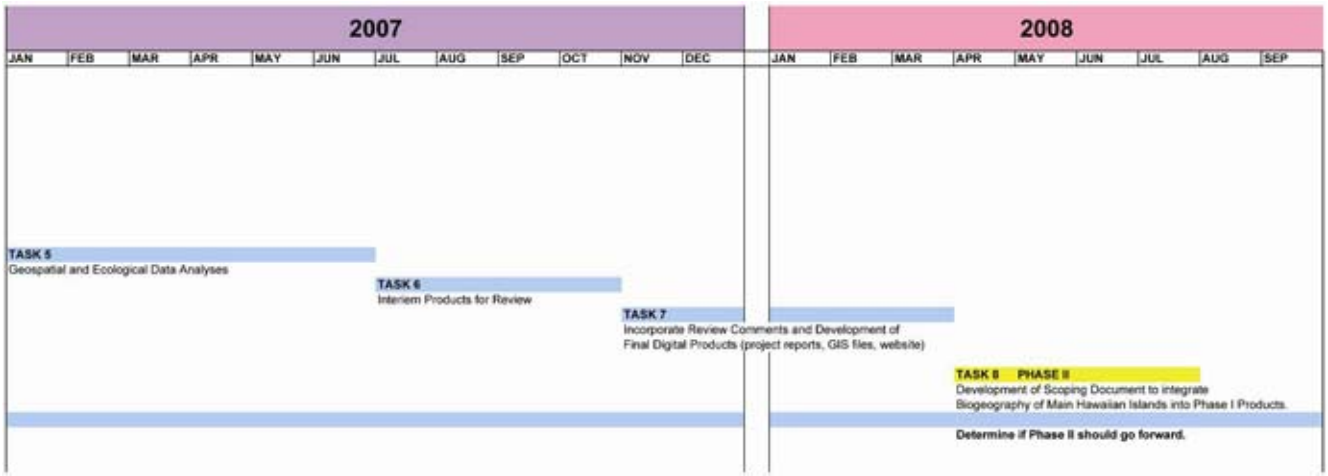
Task 9. A Web Site for the Biogeographic Assessment
(Estimated Completion Date: Ongoing throughout the duration of the project)

This password-protected web site will be configured to support the biogeographic assessment process by providing background information and project updates, and allowing for review of interim products. Visit the web site at: http://ccma.nos.noaa.gov/ecosystems/sanctuaries/nwhi.html.

SCHEDULE

Proposed Schedule for Conducting a Biogeographic Assessment of the NWHI.





PROJECT PERIOD
July 2005 through September 2008

PROJECT TEAM

The Biogeography Team of the National Centers for Coastal Ocean Science (NCCOS) will lead this collaborative effort. Other project members include staff from the Office of National Marine Sanctuaries and the Northwestern Hawaiian Islands Coral Reef Ecosystem Reserve. External partners include various individuals from the University of Miami, the University of Hawaii and Hawaii Institute of Marine Biology, and NOAA Fisheries, Coral Reef Ecosystem Division. Various other external partners, including the State of Hawaii and the U.S. Fish and Wildlife Service, will be invited to participate. Additional support and guidance will be provided by the Hawaiian Islands Coral Reef Ecosystem Reserve Advisory Council (RAC).

Contact Information

NCCOS Biogeography Team

Alan Friedlander
NWHI CRER Project Manager
808-259-3165
Alan.Friedlander@noaa.gov

Mark Monaco
Biogeography Team Manager
301-713-3028 x 160
mark.monaco@noaa.gov

Jenny Waddell
Biogeography Team
301-713-3028 x 174
jenny.waddell@noaa.gov

Ken Buja
Biogeography Team
301-713-3028 x 140
ken.buja@noaa.gov

Tracy Gill
Biogeography Team
301-713-3028 x150
Tracy.Gill@noaa.gov

Other Support:
Lisa Wedding
Laurie Bauer
2 new contract hires

NWHI CRER – NMSP

Aulani Wilhelm
NWHI CRER Reserve Manager
808-397-2660 x223
Aulani.Wilhelm@noaa.gov

Malia Chow
NWHI CRER Policy Analyst
808-397-2660 x227
Malia.Chow@noaa.gov

Randy Kosaki
NWHI CRER Research Coordinator
808-397-2660 x243
Randall.Kosaki@noaa.gov

Susan Vogt
NMSP Pacific Islands Regional Office
808-397-2404 x 259
Susan.Vogt@noaa.gov

Sean Corson
NWHI CRER Designation Coordinator
808-397-2660 x225
Sean.Corson@noaa.gov

Mitchell Tartt
NMSP Ecologist
301-713-3125 x 284
mitchell.tartt@noaa.gov

Charles Alexander
Chief, National Programs Branch (NMSP)
301-713-3125 x 247
charles.alexander@noaa.gov

Steve Gittings
NMSP Science Coordinator
301-713-7274
steve.gittings@noaa.gov

REFERENCES

Battista, T.A. and M.E. Monaco. 2004. Geographic information systems application in coastal marine fisheries. Pages 189-208 In: W.L. Fisher and R.J. Rahel, editors, Geographic information systems in fisheries. American Fisheries Society, Bethesda, MD.

Brown, S.K., K.R. Buja, S.H. Jury, M.E. Monaco, and A. Banner. 2000. Habitat suitability index models for eight fish and invertebrate species in Casco and Sheepscot Bays, Maine. North American Journal of Fisheries Management 20:408-435.

Christensen, J.D., Caldow, C., Pittman, S.J., and Monaco , M.E. (In prep) Mapping fish diversity and abundance across shallow-water marine landscapes in the Caribbean.

DeMartini E.E. and A.M. Friedlander. 2004. Spatial patterns of endemism in shallow reef fish populations of the Northwestern Hawaiian Islands. Marine Ecology Progress Series 271: 281-296.

Ehler, Rod. 2004. Socio-Economic Assessment of Commercial Bottomfishing in the Northwestern Hawaiian Islands (Draft). U.S. Department of Commerce, NOAA-NOS, National Marine Sanctuary Program, Silver Spring, MD. 32pp.

Emmett, R.L., S.L. Stone, S.A. Hinton and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in West Coast estuaries, Volume II, Species Life History Summaries. ELMR Report No. 8 NOAA/NOS SEA Division, Rockville, MD 329 p.

Firing, J.B., R. Brainard and E. Firing. 2004. Ten years of shipboard ADCP measurements along the Northwestern Hawaiian Islands. Northwestern Hawaiian Islands: 3rd Scientific Symposium, Honolulu. 18 pp.

Friedlander, A.M. and E.E. DeMartini. 2002. Contrasts in density, size, and biomass of reef fishes between the northwestern and the main Hawaiian islands: the effects of fishing down apex predators. Marine Ecology Progress Series. Vol 230: 253-264.

Friedlander, A.M. and J.D. Parrish. 1998. Habitat characteristics affecting fish assemblages on a Hawaiian coral reef.Journal of Experimental Marine Biology and Ecology 224 (1): 1-30.

Friedlander, A.M., E.K. Brown, P.L. Jokiel, W.R. Smith and S.K. Rodgers. 2003. Effects of habitat, wave exposure, and marine protected area status on coral reef fish assemblages in the Hawaiian archipelago. Coral Reefs 22: 291-305

Friedlander, A.M., G. Aeby, R. Brainard, A. Clark, E. DeMartini, S. Godwin, J. Kenyon, R. Kosaki, J. Maragos, P. Vroom. 2005. The State of Coral Reef Ecosystems of the Northwestern Hawaiian Islands. pp. 270-311. In: J. Waddell (ed.), The State of Coral Reef Ecosystems of the United States and Pacific Freely Associated States: 2005. NOAA Technical Memorandum NOS NCCOS 11. NOAA/NCCOS Center for Coastal Monitoring and Assessment's Biogeography Team. Silver Spring, MD. 522 pp.

Gill, T.A., M.E. Monaco, S.K. Brown, and S.P. Orlando. 2001. Three GIS tools for assessing or predicting distributions of species, habitats, and impacts: Coastal Ocean Resource Assessment (CORA), Habitat Suitability Modeling (HSM), and Coastal Assessment and Data Synthesis (CA&DS). *In*: Proceedings of the First International Symposium on Geographic Information Systems (GIS) in Fishery Sciences, Seattle, Washington, USA; 2-4 March 1999. Saitama, Japan. pp 404-415.

GCRMN, 2004. Ed. C.R. Wilkinson. Status of Coral Reefs of the World: 2004. Australian Institute of Marine Science. Townsville, Australia.

Juvik S.P. and J.O. Juvik. 1998. Atlas of Hawaii, third edition. University of Hawaii Press, Honolulu.

Kendall, M.S., and M.E. Monaco. 2003. Biogeography of the National Marine Sanctuaries: A Partnership between the National Marine Sanctuary Program and the National Centers for Coastal Ocean Science Biogeography Program. Unpublished Report. 15 pp.

Maragos J.E., D.C. Potts, G. Aeby, D. Gulko, J. Kenyon, D. Siciliano and D. Van Ravenswaay. 2004. 2000-2002 Rapid Ecological Assessment of Corals (Anthozoa) on Shallow Reefs of the Northwestern Hawaiian Islands. Part I: Species and Distribution. Pacific Science 58 (2): 211-230.

Miller, J.E., R.K. Hoeke, T.B. Appelgate, P.J. Johnson. 2003. Bathymetric Atlas of the Northwestern Hawaiian Islands, Draft—May 2003. National Oceanic and Atmospheric Administration and Hawaii Mapping Research Group. 65pp.

Monaco, M., Kendall, M., Higgins, J., Alexander, C., and Tartt, M., (2005) Biogeographic assessments of NOAA National Marine Sanctuaries: The integration of ecology and GIS to aid in marine management boundary delineation and assessment, in Wright, D.J. and Scholz, A.J. (Eds.), "Place Matters: Geospatial Tools for Marine Science, Conservation, and Management in the Pacific Northwest," Corvallis, OR: Oregon State University Press, 2005.

Monaco, M.E., and J.D. Christensen. 1997. Biogeography Program: Coupling species distributions and habitat. Pages 133-139 *in* G.W. Boehlert and J.D. Schumacher, editors. Changing oceans and changing fisheries: Environmental data for fisheries research and management. National Marine Fisheries Service Technical Memorandum NOAA-TM-NMFS-SWRSC-239, Pacific Grove, California.

Monaco, M.E., T.A. Lowery, and R.L. Emmett. 1992. Assemblages of U.S. West Coast estuaries based on the distribution of fishes. J. Biogeography 19:251-267.

NOAA. 2003a. Atlas of the Shallow-Water Benthic Habitats of the Northwestern Hawaiian Islands (Draft). Silver Spring, MD. 160pp.

NOAA National Centers for Coastal Ocean Science (NCCOS) 2003b. A biogeographic assessment off North/Central California: To support the joint management plan review for Cordell Bank, Gulf of the Farallones, and Monterey Bay National Marine Sanctuaries: Phase I – Marine fishes, birds, and mammals. Prepared by NCCOS's Biogeography Team in cooperation with the National Marine Sanctuary Program. Silver Spring, MD 145 pp

NOAA National Centers for Coastal Ocean Science (NCCOS) 2005. A biogeographic assessment of the Channel Islands National Marine Sanctuary: A review of boundary expansion concepts for NOAA's National Marine Sanctuary Program. Prepared by NCCOS's Biogeography Team in cooperation with the National Marine Sanctuary Program. Silver Spring, MD NOAA Technical Memorandum NOS NCCOS 235 pp.

Pattillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco. 1997. Distribution and abundance of fishes and invertebrates in Gulf of Mexico estuaries., Volume II: Species life history summaries. ELMR Report No. 11. NOAA/NOS/SEA Division, Silver Spring, MD 377 pp.

Rubec, P.J., J.C.W.Bexley, H.Norris, M.S. Coyne, M.E. Monaco, S.G. Smith and J.S. Ault. 1999. Suitability modeling to delineate habitat essential to sustainable fisheries. American Fisheries Society Symposium 22:108-133.